Recent Higgs results from ATLAS

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1 Introduction

The search for the Higgs boson, both in Standard Model and Beyond Standard Model scenarios is one of the key aims of the Large Hadron Collider (LHC) at CERN. While the Higgs boson is not discovered yet, limits have been set on its mass by LEP and Tevatron, excluding, in the case of the SM scenario, a Higgs boson below 114.4 GeV and in the range $158-175$ GeV at 95 % CL, while current indirect constraint from electroweak fit gives a most probable mass of $120.6^{17.9}_{-5.2}$ GeV. Based on a total luminosity varying from 35 pb^{-1} to 209 pb^{-1} collected by the ATLAS detector either in 2010 or 2011, ATLAS searched for the Higgs boson in several channels both in Standard Model and Beyond Standard Model scenarios. The limit-setting procedure uses the power-constrained profile likelihood method known as the Power Constrained Limit, PCL Results were computed also with the CL_S technique for comparison with the Tevatron and LEP results.

2 Search for the Higgs

The search for the Higgs in the $H \to \gamma\gamma$ channel selects two isolated high-p_T photons. Two analyses are made, one with 38 pb^{-1} of data recorded in 2010, used for the combination of all decay channels in the search for the Standard Model Higgs boson, and one based on 209 pb^{-1} of 2011 data [1], with an improved method for the measurement of the photon direction using calorimeter information and an increased photon isolation threshold due to the change of pile-up conditions. The main background, made from genuine prompt di-photon events and reducible background γj and jj, with one or two jets misidentified as a photon, has been measured by extrapolation of background-rich control regions into the signal region, using the calorimeter isolation and the quality of the photon identification. The contribution of the Drell-Yan background $Z/\gamma^* \to ee$ with electrons misidentified as photons, is measured in the region of the Z boson mass peak and extrapolated into the signal region beyond 100 GeV. A good agreement is observed with expectations from the simulation. The final discriminant variable for the evaluation of the exclusive limits is the invariant mass of two photons. A fit is performed to the observed distribution in the data using a decreasing exponential function for the background description. The resulting exclusion limits reach down to $4.2 \times SM$ for the analysis based on 2011 data.

The $H \to WW^{(*)} \to l\nu l\nu$ analysis is performed with 35 pb^{-1} of data recorded in 2010. The selection requests exactly two isolated oppositely charged leptons. A low and high di-lepton invariant mass cuts are used to reject respectively the Y resonance and the background from top production and Z resonance. Missing transverse energy is requested to be above 30 GeV. To take advantage of the angular correlations between the leptons from the spin-0 nature of the Higgs boson, the azimutal angle $\Delta\phi_{ll}$ is required to be below a certain threshold. Background contributions from WW, top and $W + jets$ production are normalised using control regions in data. The final discrimination variable is the transverse mass. The expected exclusion limit reaches down to $2.4 \times SM$ for the Higgs boson mass $m_H = 160$ GeV.

The $H \to WW \to l\nu qq$ analysis is performed with 35 pb^{-1} of data recorded in 2010. The event selection requires the presence of exactly one lepton in the final state. Missing transverse energy is required to be above 30 GeV. Events with fewer than two jets or with presence of a $b-jet$ are rejected. The di-jet mass is constrained to be consistent with the mass of the W boson. The dominant background originates from $W+jets$ and top production, with minor background from WW, WZ, $Z+jets$ and QCD dijets. The background is estimated by fitting a sum of templates from simulation to the data. The final discriminant variable is the four-object invariant mass $m_{l\nu qq}$ with the constraint for $m_{l\nu}$ to be consistent with the mass of the W boson. For $m_H = 400$ GeV, the exclusion limit is $11.2 \times SM$.

The gold-plated $H \to ZZ^{(*)} \to llll$ channel benefits from a fully reconstructed final state, which leads to a narrow four-lepton invariant mass peak on top of a continuous background, but has small rates. The selection requires two pairs of oppositely charge and isolated same-flavour leptons, with one di-lepton mass compatible with the Z boson mass and the second di-lepton mass exceeding a certain threshold dependending on the Higgs boson mass. Background are measured from control regions. After all cuts on 40 pb^{-1} of data recorded in 2010, no events survive the selection. The exclusion limit is $24 \times SM$ for $m_H = 200$ GeV. The decays $H \to ZZ \to ll\nu\nu$ and $H \to ZZ \to llqq$ have higher branching ratios but more background and less clean mass resolutions. To reduce the amount of background, these channels are considered in the range $200 < m_H < 600$ GeV where the two Z bosons are on-shell. The selection requires two same-flavour leptons and a di-lepton mass compatible with the mass of the Z boson. For the $H \to ZZ \to ll\nu\nu$ channel, a minimum amount of missing transverse energy is required, as well as azimutal di-lepton angle $\Delta\Phi_{ll}$ to be below a certain threshold, and the $b - tagged$ jets are vetoed to reduce the top background. For the $H \to ZZ \to llqq$ channel, the missing transverse energy is required to be below a certain threshold, the di-jet mass is required to be compatible with the mass of the Z boson. The background is evaluated from control samples. The final discriminant variables are respectively the transverse and the invariant mass for the two channels. The combined observed exclusion limits are in the range of 3.5 to $39 \times SM$.

In the combination of the analyses using 2010 data, the following channels are considered : $H \to \gamma\gamma$ with 38 pb^{-1}, $H \to WW \to l\nu qq$ and $H \to WW^{(*)} \to l\nu l\nu$ each with 35 pb^{-1}, $H \to ZZ \to llll$ with 40 pb^{-1}, $H \to ZZ \to ll\nu\nu$ and $H \to ZZ \to llqq$ with 35 pb^{-1}. Correlations between channels are propagated into the calculation of the combined exclusion limits. Theoretical models with the Higgs mechanism and a fourth generation of heavy quarks and leptons can be excluded for the Higgs boson masses from 140 GeV to 185 GeV.

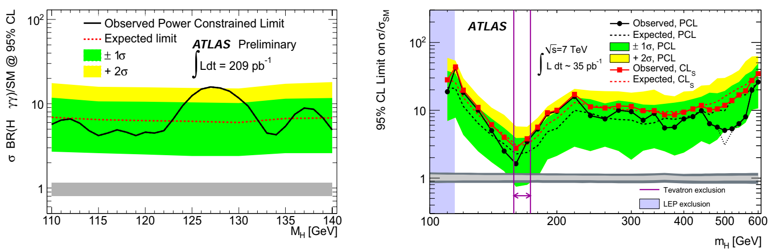
In the $MSSM$ scenario, the Higgs boson is searched in the decay to pair of τ leptons [4]. The event selection requires the presence of exactly one electron or muon in the final state, isolated, with opposite charge as compared to the one of the reconstructed hadronic τ decay. A minimum missing transverse energy and a maximum transverse mass for the di-τ system are required. The main background contributions ($Z \to \tau\tau$, W+jets, multijet production) are extrated from control samples. The final discriminant is the transverse mass. The resulting exclusion region of the $MSSM$ parameter space exceeds the one reached by Tevatron.

In the $NMSSM$ scenario, the light CP-odd Higgs boson a_1 is searched [3] in its decay to pair of muons in the mass range $6-9$ GeV and $11-12$ GeV, excluding the region $9-11$ GeV where the uncertainty on the expected rate of Υ resonances is too important to allow for distinguishing an additional resonance in this mass range. The selection requires two oppositely charged muons consistent with coming from the decay of a single particle. A likelihood method, based on the χ^2 of the dimuon vertex fit and the muon isolation, is used to reduce the combinatorial background. The probability density functions (PDFs) are derived from data. The background PDF is extracted from a sideband of the dimuon invariant mass. The signal PDF is constructed from events around the $\Upsilon(1S)$ resonance after having substracted the expectation from the background in the signal region, in agreement with the PDF from simulation of a_1 only. Upper limits on the cross-section times branching ratio of a_1 in the channel are derived. An important impact of look-elsewhere effect has been taken into account.

3 Conclusion

The ATLAS search for the Higgs boson in the mass range from 110 GeV to 600 GeV in 35 pb^{-1} to 209 pb^{-1} of data recorded in 2010 or 2011 has been presented. With this luminosity, no excess of events is observed as compared to predicted background rates. There is not enough sensitivity to exclude the existence of the Standard Model

Higgs boson. However, exclusion limits on it's production rate are computed. The analysis in the $H \to \gamma\gamma$ channel with 2011 data provides the current best world limit (Fig. 1 a) for this channel at this conference, while the combination of analyses in several decay channels with 2010 data (Fig. 1 b) gives the most stringent constraints to date for Higgs boson masses above 250 GeV and are close to the Tevatron limits at intermediate masses. An extension of the Standard Model, assuming the Higgs mechanism and adding a fourth generation of heavy quarks and leptons, is excluded for Higgs boson masses between 140 and 185 GeV.



(a) (b)

Figure 1: Expected and observed upper limits on the total cross-section divided by the expected Standard Model Higgs boson cross section, for (a) the $H \to \gamma\gamma$ analysis [1] with 209 pb^{-1} of 2011, and (b) for the combination [2] of several channels of 2010.

References

[1] The ATLAS collaboration, Search for the Higgs Boson in the Diphoton Channel with the ATLAS detector using 209 pb^{-1} of Data taken in 2011, ATLAS-CONF-2011-085, http://cdsweb.cern.ch/record/1356193

[2] The ATLAS collaboration, Limits on the production of the Standard Model Higgs Boson in pp collisions at $\sqrt{s} = 7\ TeV$ with the ATLAS detector, arXiv:1106.2748 (2011).

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